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DEVELOPMENT OF FAST HELIUM BEAM EMISSION SPECTROSCOPY FOR TOKAMAK PLASMA DENSITY- AND TEMPERATURE DIAGNOSTICS

E. Galutschek[1], M. Proschek[1], H.D. Falter[1], H. Anderson[2], Y. Andrew[3], M. de Baar[4], M. Brix[5], S. Cox[3], P. Franzen[5], C. Giroud[4], C. Maggi[6], Andrew Meigs[3], A. Stäbler[6], J. Schweinzer[6], E. Wolfrum[6] , F. Aumayr[1], HP. Winter[1], and EFDA JET contributors

[1]*Institut f. Allgemeine Physik, TU-Wien, A-1040 Wien, Wiedner Hauptstrasse 8-10 (Association EURATOM-OEAW)*
[2]*Dept. of Physics and Applied Physics, Univ. of Strathclyde, Glasgow, UK*
[3]*UKAEA-Euratom Association, Culham Science Centre, Abingdon, OXON, OX14 3EA, UK*
[3]*EFDA-JET CSU, Building K1, Culham Science Centre, Abingdon, OXON, OX14 3EA, UK*
[4]*FOM Instituut voor Plasmafysica Rijnhuizen, EURATOM Association, Postbus 1207, NL-3430 BE Nieuwegein, The Netherlands**
[5]*Institut für Plasmaphysik, Forschungszentrum Jülich GmbH, EURATOM Association, D-52425 Jülich, Germany**
[6]*Max-Planck-Institut für Plasmaphysik, EURATOM Association, D-85748 Garching*
** partner in the Trilateral Euregio Cluster*

Introduction

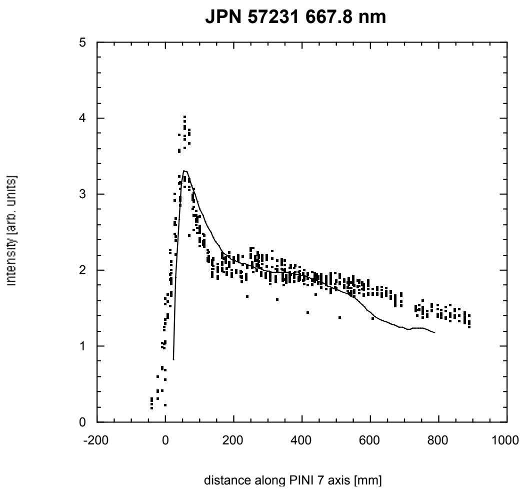
Optical emission from energetic lithium beams [1] has been successfully used as a diagnostics of tokamak plasma density. Electron temperature as well as plasma density can be measured with thermal helium diagnostic beams [2]. However, both beam emission spectroscopies (BES) are limited in range to the outer plasma region because of small penetration depth of the injected neutral particles. More energetic (≥ 20 keV) helium atoms penetrate much deeper into the plasma and therefore offer the prospect of locally measuring electron temperature and plasma density over a much wider range. Of particular interest are such measurements with good spatial resolution extending over H-mode and internal transport barriers. For developing electron density and -temperature diagnostics based on fast He beam emission spectroscopy (fast He-BES), we have performed in recent years different proof-of-principle experiments at ASDEX Upgrade (AUG) in Garching and JET in Culham. Thereby measured HeI emission profiles showed fair agreement with simulated ones for given plasma density-, temperature- and impurity distributions, utilizing a collisional-radiative model [3] and atomic collision data supplied by the ADAS group [4]. Sufficiently intense He diagnostic beams are now obtained by puffing a small amount of helium into a standard deuterium heating beam ion source, such producing a "doped" diagnostic He beam [5]. The experiments made use of on-site beam emission spectroscopy systems which provided suboptimal geometry for observing the Doppler-shifted HeI line emission from the injected He diagnostic beam.

Out of eleven HeI emission lines observed, seven showed sufficient intensity and the 667.8 nm (2^1P-3^1D) singlet- and the 587.6 nm (2^3P-3^3D) triplet line proved to be most suitable. A "reversion code" based on ADAS model calculations [6] has been developed to iteratively reconstruct plasma density- and temperature profiles from the measured HeI intensity profiles. Until recently, this "reversion code" was only tested with synthesized emission profiles.

Recent experimental results and model calculations

For further testing fast He-BES with real plasma data, emission profiles for the two above mentioned HeI lines were collected for different plasma discharges during a campaign at AUG in June 2002 and two dedicated experimental sessions at JET in September and October 2002. As first example we show He-BES profiles measured for a JET L-mode discharge (pulse #57231). The 110 keV diagnostic He beam was produced by He doping [5] of one of the JET heating beams (PINI 7 at Octant 8). This diagnostic beam was observed with multichannel optical spectrometers (with 9 and 12 channels, respectively). To enlarge the range of spectral observation, the plasma discharge was moved by about 12 cm via inward and outward sweeping during the data aquisition phase.

In Fig. 1 we display our measured HeI emission profiles for the 587.6 nm and 667.8 nm lines, together with forward-modelled profiles obtained from the ADAS based code *SCOTTIE* [6], using raw plasma profiles from the JET core lidar diagnostics. The code reproduces reasonably well the considerably faster decay of the HeI 3^3D state as compared to the 3^1D state. The outermost structure of the singlet emission profile is related to a relatively small metastable 2^1S He diagnostic beam admixture which results from the charge exchange of He^+ ions in the D_2 neutralisation gas in the heating beam.



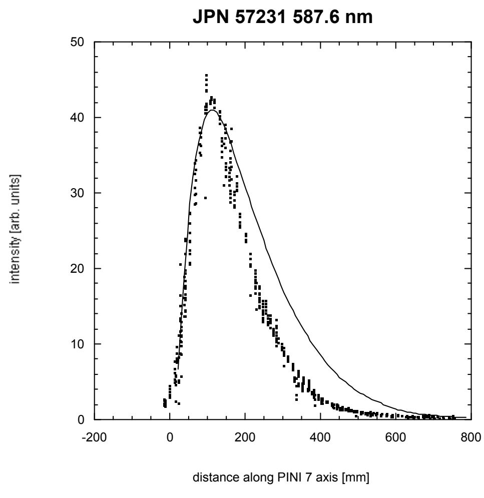


Fig. 1: Measured (dots) and modelled (line) HeI beam emission profiles of JPN 57231, plotted along the axis of the injected helium beam. (helium doped PINI 7)

Nevertheless, the quality of the He beam emission profiles calculated by SCOTTIE has to be further improved, to be successfully used for an iterative reconstruction of plasma profiles. As our second example, fig. 2 shows a very first results from our “reversion code”. The plasma density- and temperature profiles for JET pulse number 57189 have been reconstructed using the measured He beam emission profiles together with density- and temperature profiles obtained from JET standard diagnostics as input for the “reversion code”. Starting with this temperature profile and an arbitrarily chosen unphysical (position independent) density profile, a reconstruction of the plasma density profiles from the 667.8 nm 2^1P-3^1D line only is shown in fig. 2. For reconstruction of the temperature profile from the measured density profile, both BES profiles had to be utilized and a physically realistic starting profile for the temperature was necessary for achieving convergence. Also, a very simple parametrisation of the plasma density- and temperature profile had to be used for these first calculations. Reconstructing the plasma profiles section by section instead of considering the whole profile at once will not only allow to use a more sophisticated parametrisation, but also prevent discrepancies as seen for the inner part of the density profile reconstruction. The development of such a “reversion code” is under way.

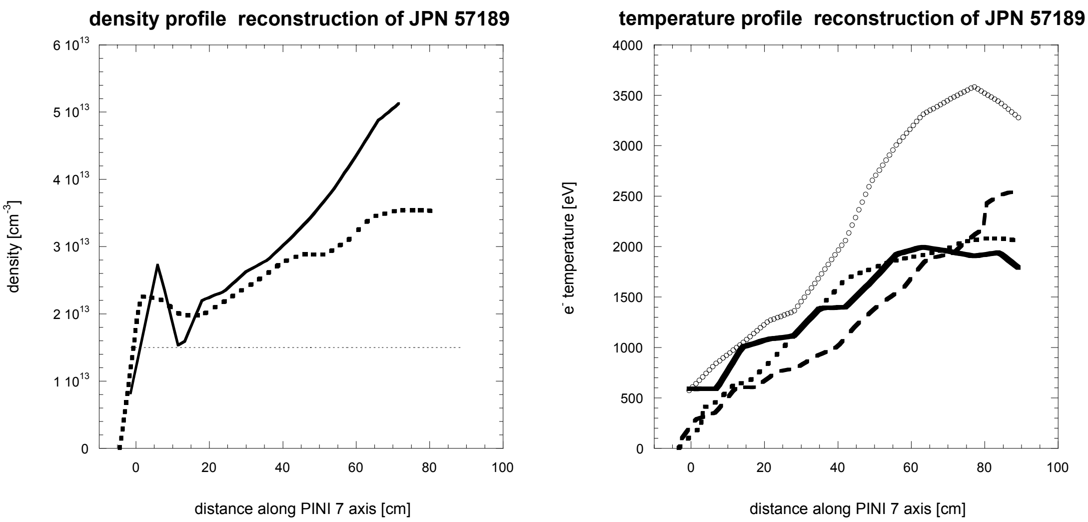


Fig. 2: Plasma density- and temperature reconstruction for JPN 57189, plotted along the axis of the injected helium beam. (He doped PINI 7)

Full curve in both graphs: reconstructed profiles
dotted curves in both graphs: core- and edge lidar density and temperature profiles
dashed curve in right graph: ECE temperature profile
small dots in left graph (flat line): starting situation for density reconstruction
open circles in right graph: starting situation for temperature reconstruction.

Summary and outlook

According to our most recent experience, measuring plasma density profiles is feasible by means of fast He-BES, and we have now first indications that the above mentioned HeI triplet and singlet line profiles are sufficiently sensitive to the electron temperature for also permitting the reconstruction of the plasma temperature profile. Further studies involving additional experimental data are presently under way. Measured beam emission profiles for AUG have been successfully modelled, but their spatial resolution so far has been insufficient for successfully applying our reconstruction code.

Acknowledgment

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